07.08.2019

# Digital Image Processing (CSE/ECE 478)

## Lecture 3 : Intensity Transforms and Histogram Processing

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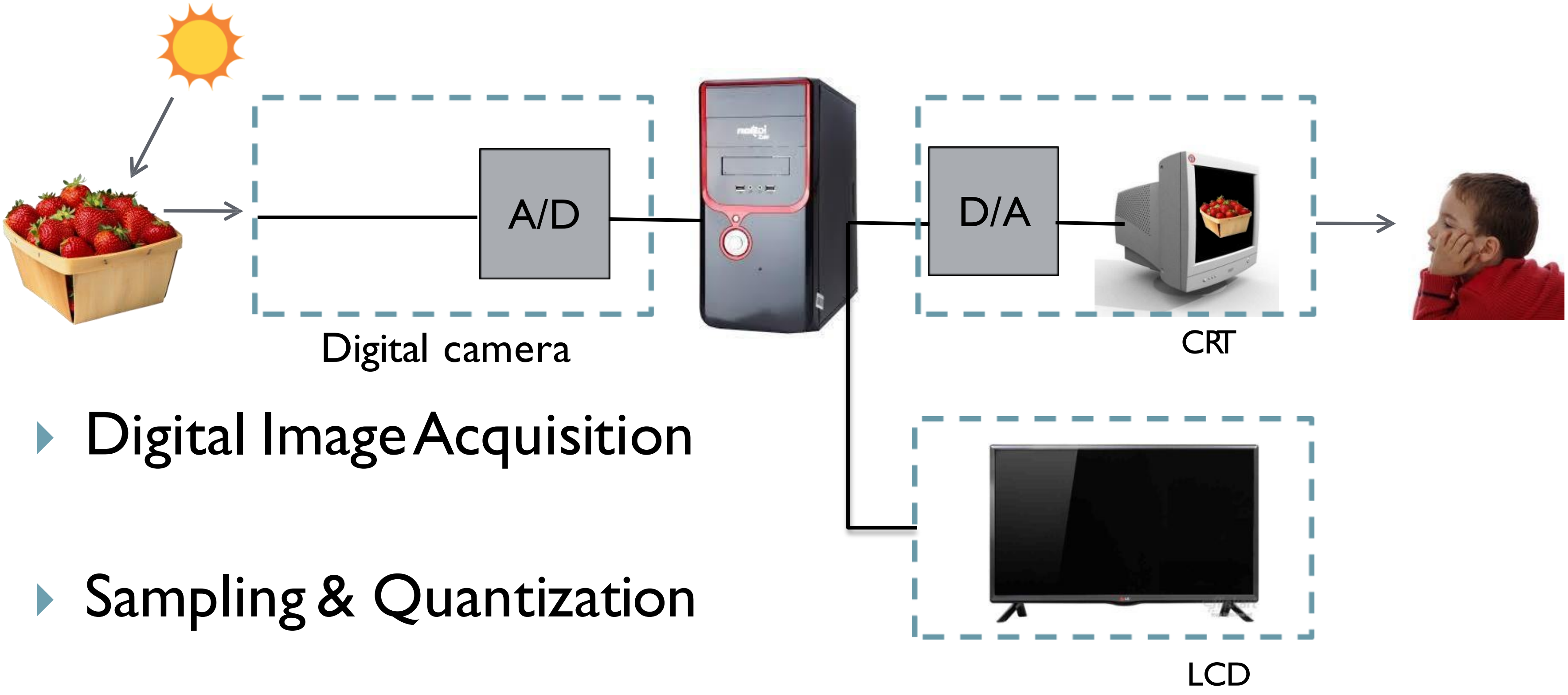
# Announcements

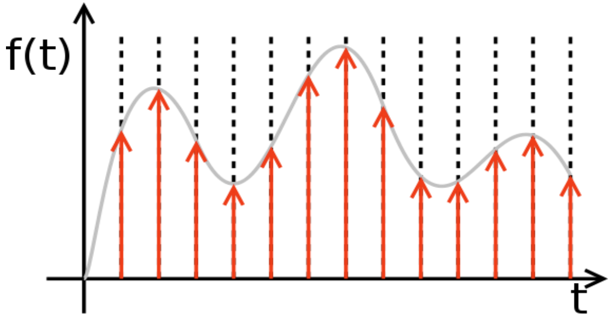
- Assignment – I will be released today
- Tutorials will start from this Saturday
  - 3.30PM – 4.30PM
  - H-203
- Add/Drop is done

# Previous Lecture



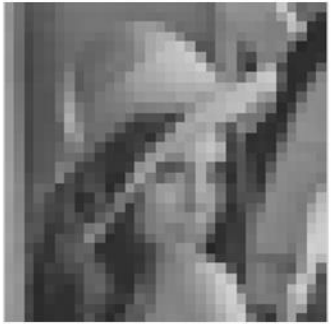

- Digital Image Acquisition
- Sampling & Quantization

# Recap …

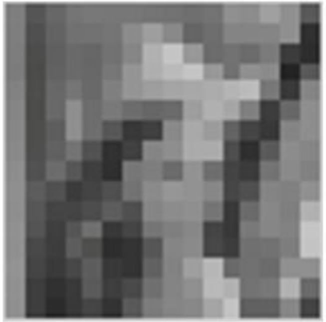



## Sampling

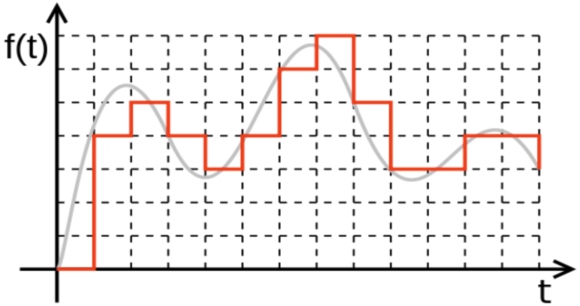
256 × 256



32 × 32



16 × 16




## Quantization

8 bits per pixel

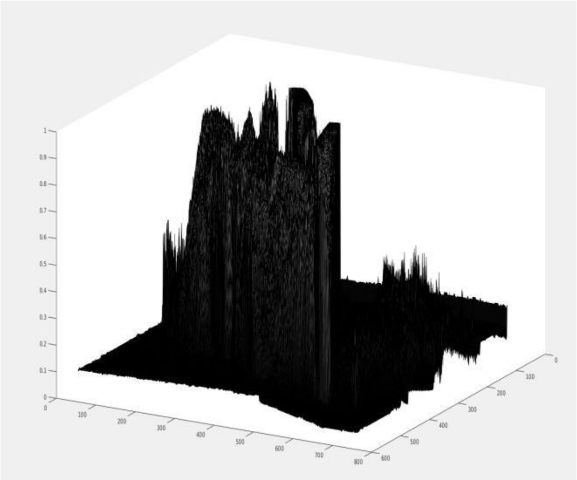
4 bits per pixel

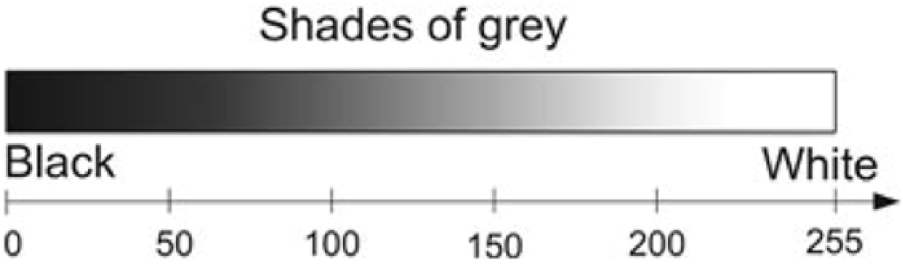
2 bits per pixel

1 bit per pixel

# Image as a function / 3D surface

- $f(x,y) = z$
- Domain : (x,y)
- Range = Intensity

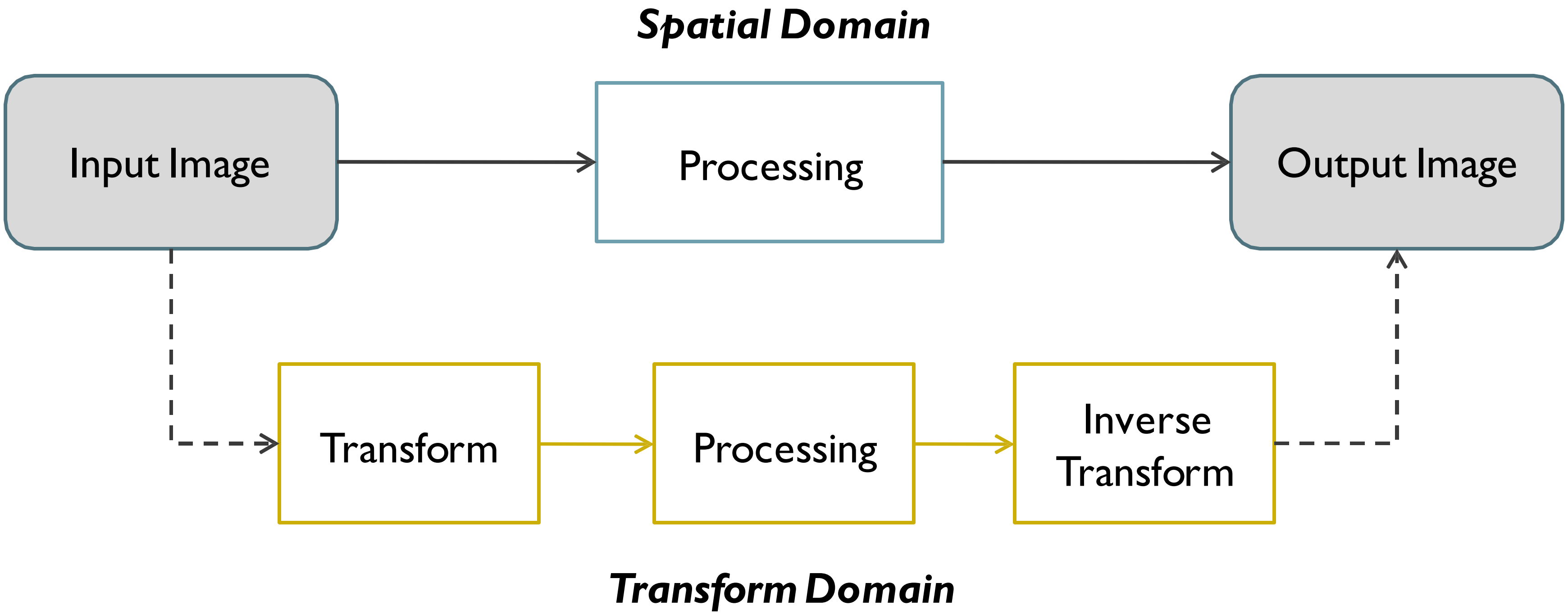




# Image Processing – Two Paradigms

- Directly manipulating pixels in spatial domain
- Manipulating in transform domain

# Spatial vs. Transform Domain Processing



# Spatial vs. Transform Domain Processing

Bandhani / Bandhej

Tie Dye

# Spatial vs. Transform Domain Processing

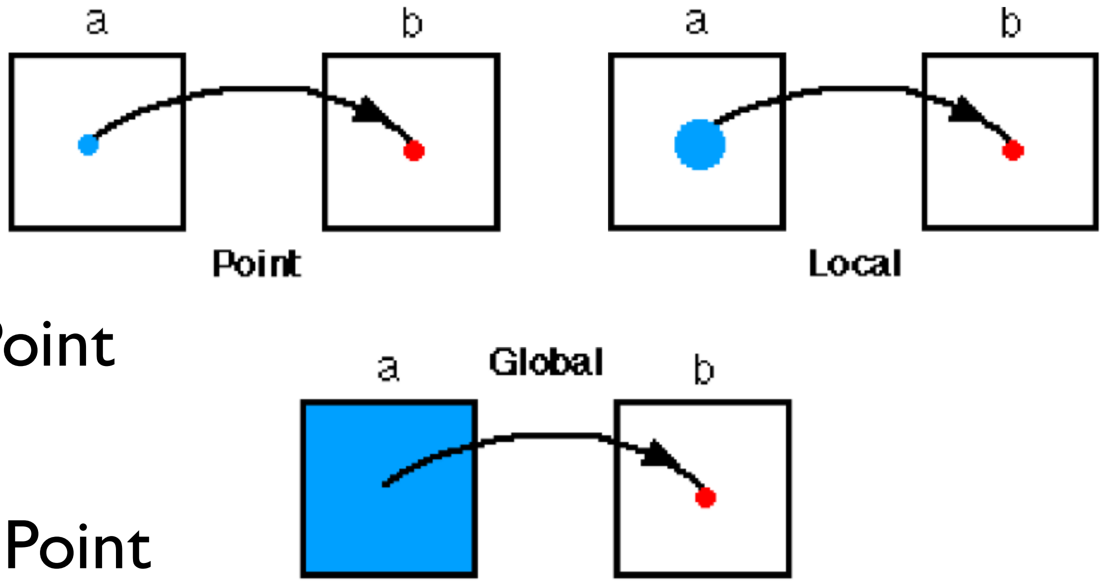
Transform (Tie)

Process (Dye)

Inverse Transform (Untie)

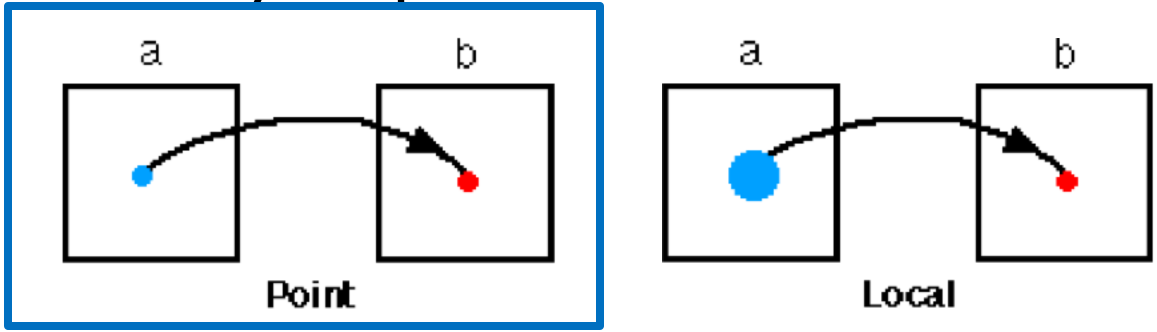
# Spatial Domain Processing

- Manipulating Pixels Directly in Spatial Domain
- Point to Point
- Neighborhood to Point
- Global Attribute to Point

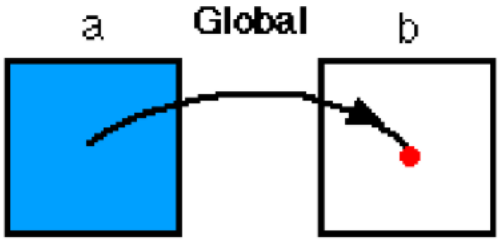


# Spatial Domain Processing

- Manipulating Pixels Directly in Spatial Domain
- **Point to Point**




- Neighborhood to Point




- Global Attribute to Point

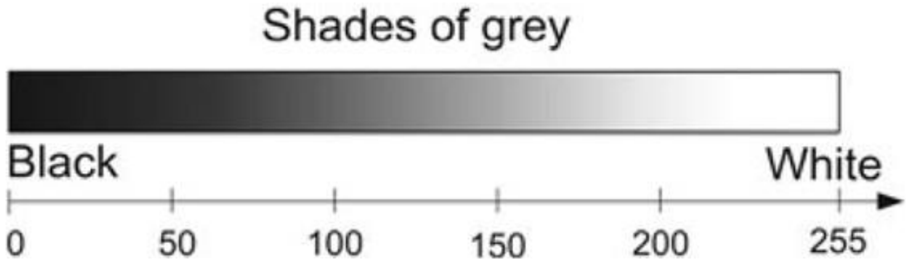
# Intensity Transforms

- $f(x,y) = z$
- $z' = g(z) = g(\ f(x,y)\ )$
- Function g is a mapping between intensity value **z** at pixel (x,y) to a new value **z'**

# Intensity Transforms

- $g = z + K$
- $g = z - K$
- $g = Kz$
- $g = K_1 z + K_2$

What is common?



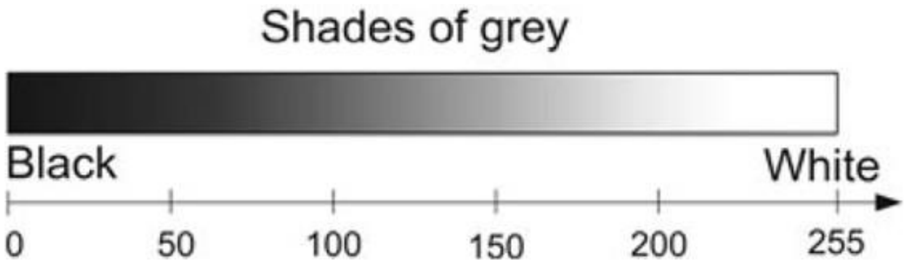
# Intensity Transforms

- $g = z + K$
- $g = z – K$
- $g = Kz$
- $g = K_1z + K_2$

Linear Transforms

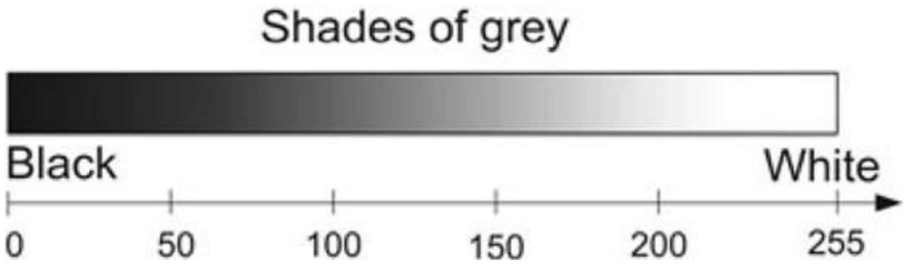
# Intensity Transforms

- What form can function g take ?
- Are there any constraints ?

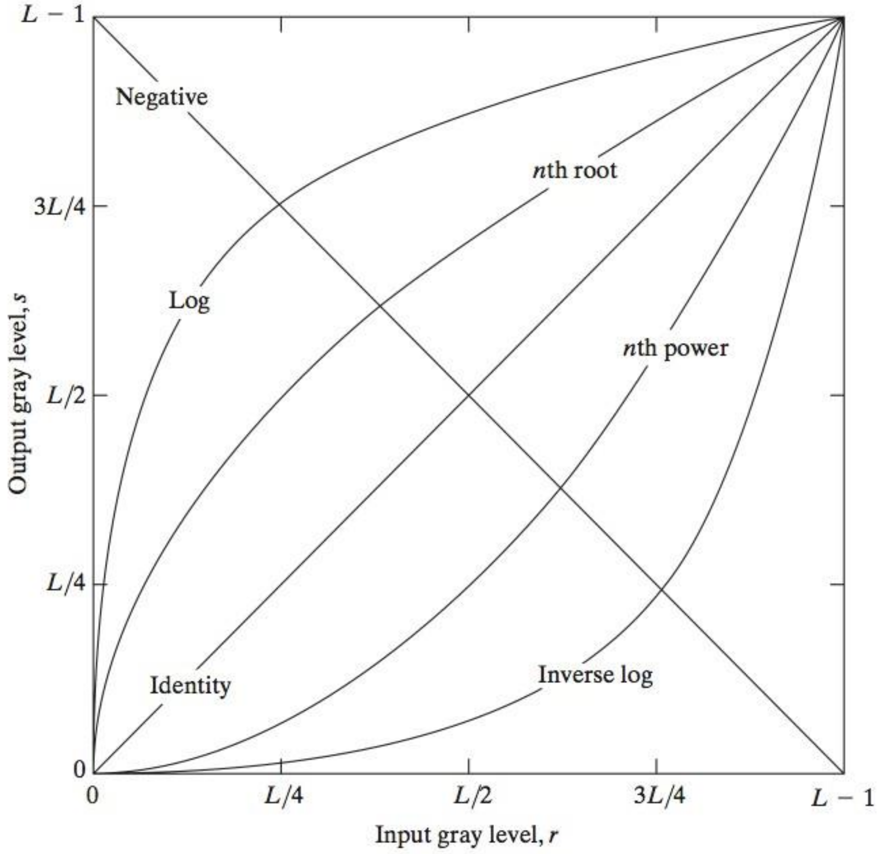


# Intensity Transforms

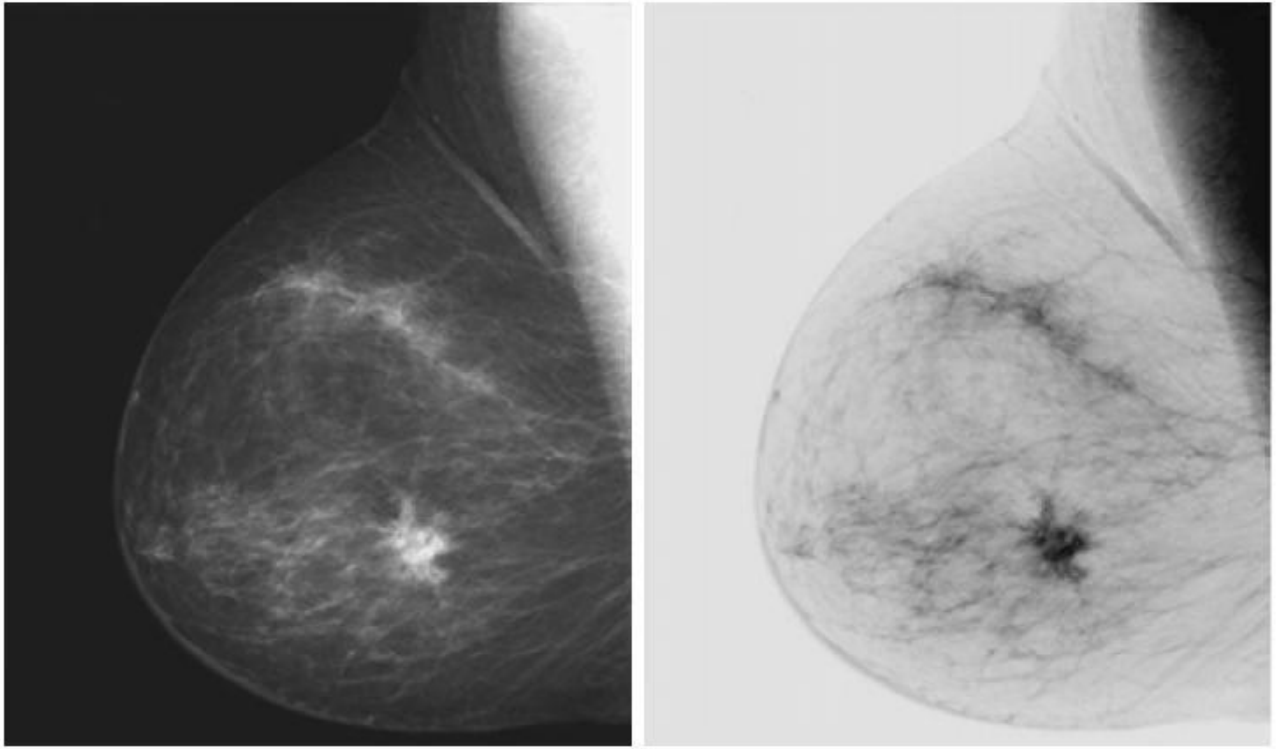
- What form can function g take ?
- Are there any constraints ?
    - Clamp to [0,255]



# Standard Intensity transformations



# Image Negatives



a b

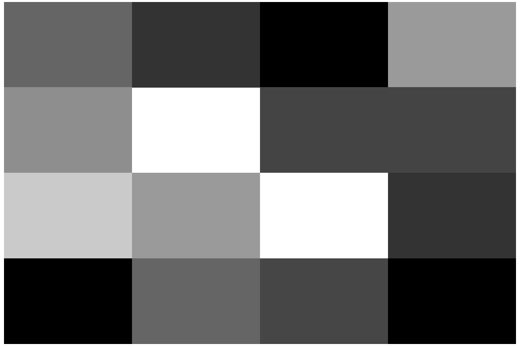
**FIGURE 3.4**
(a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

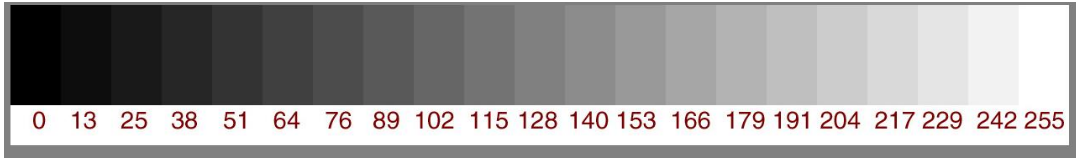
Intensity levels: $[0, L-1]$ Transformation: $s = T(r) = L - 1 - r$

# What is a digital image?

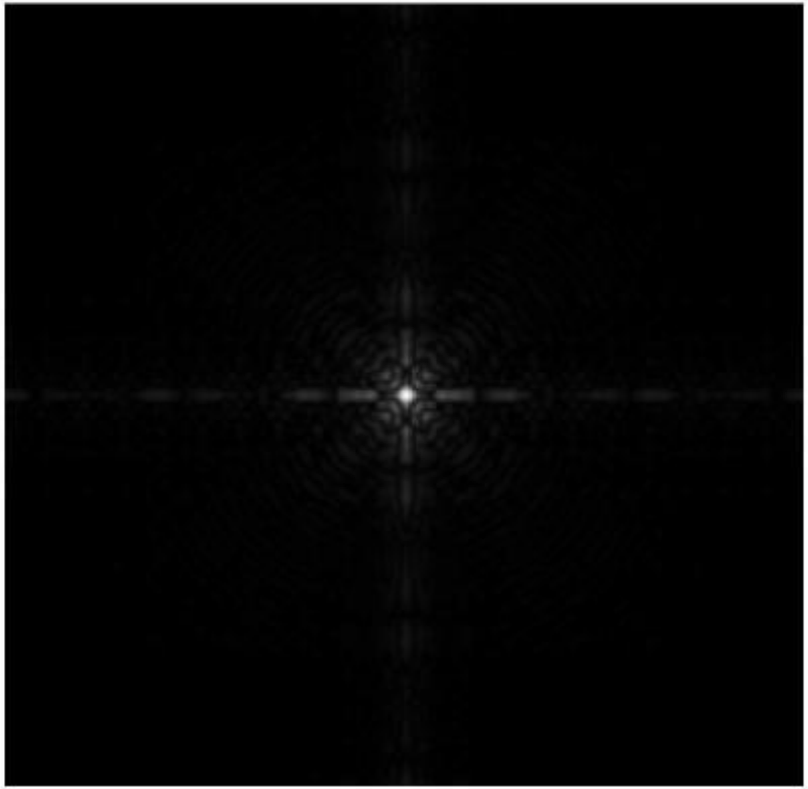
2D matrix of intensities (gray or color values) or numbers

| | | | |
|---|---|---|---|
| 100 | 50 | 0 | 150 |
| 90 | 255 | 70 | 70 |
| 200 | 150 | 255 | 50 |
| 0 | 100 | 80 | 0 |



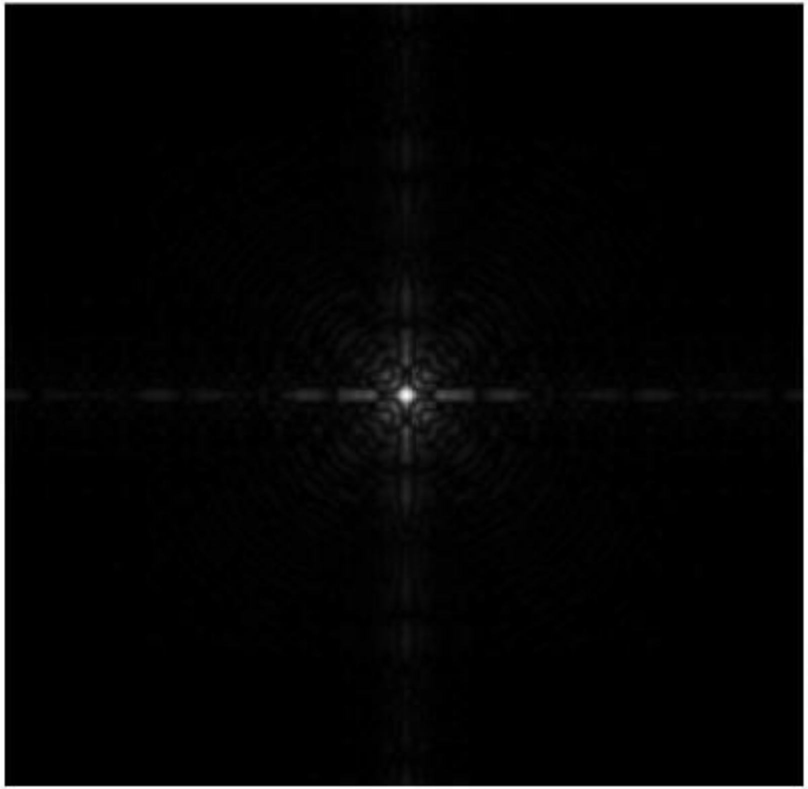


# Fourier Magnitude Spectrum



Range : $[0, 10^6]$

# Fourier Magnitude Spectrum



- Clamp to [0, 255]
- Normalize to min : $J = \frac{I}{min(I)}$
- Normalize to max : $J = \frac{I}{max(I)}$
- Normalize to range :

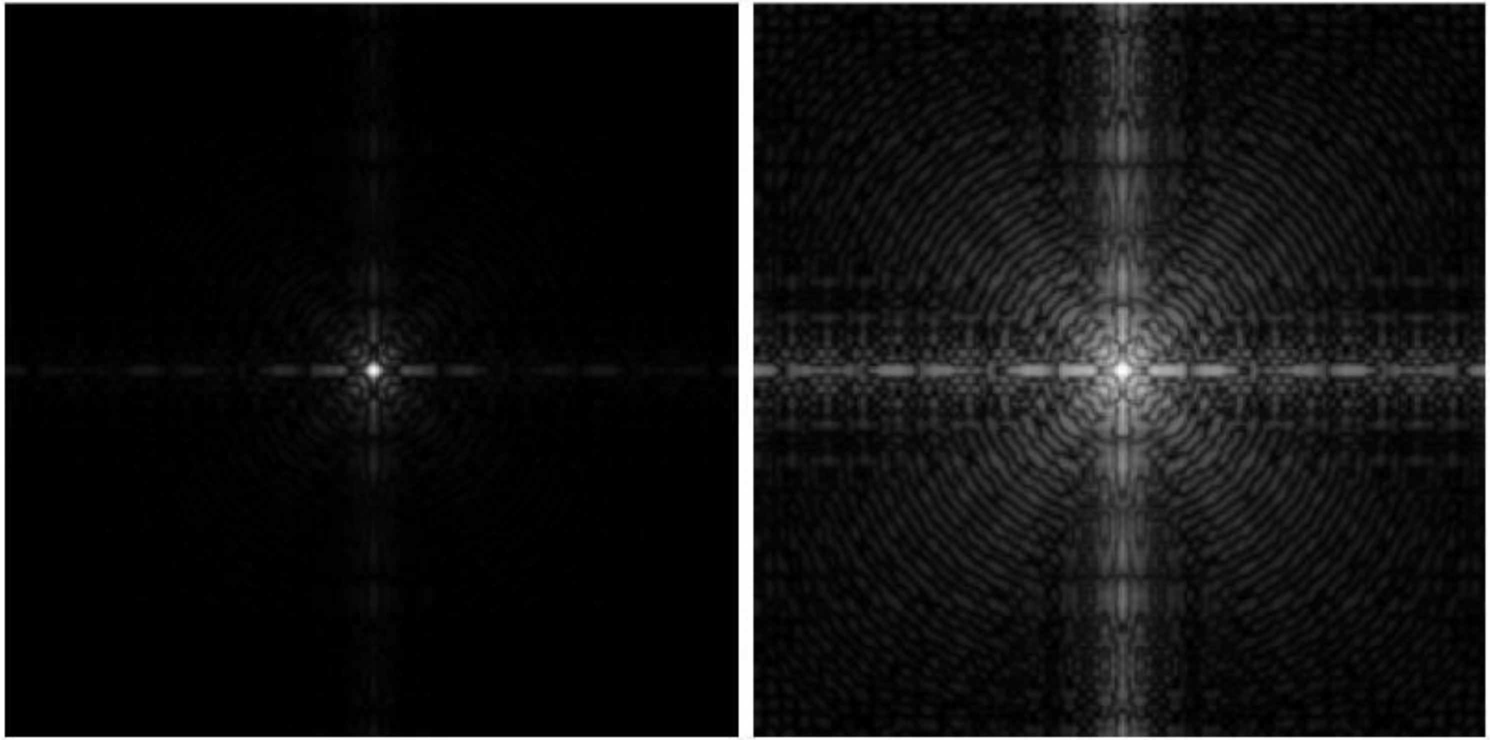
$$J = \mathtt{round}\left(255 * \frac{I - min(I)}{max(I) - min(I)}\right)$$

Range : $[0, 10^6]$

# Log Transformations

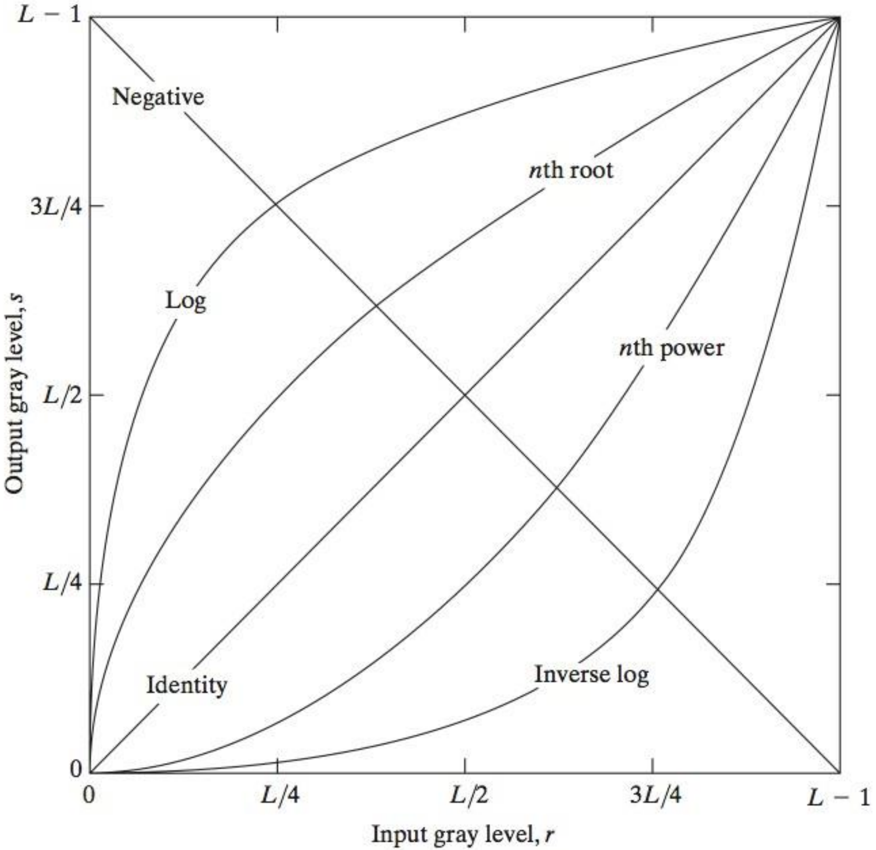
a b

**FIGURE 3.5**
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.

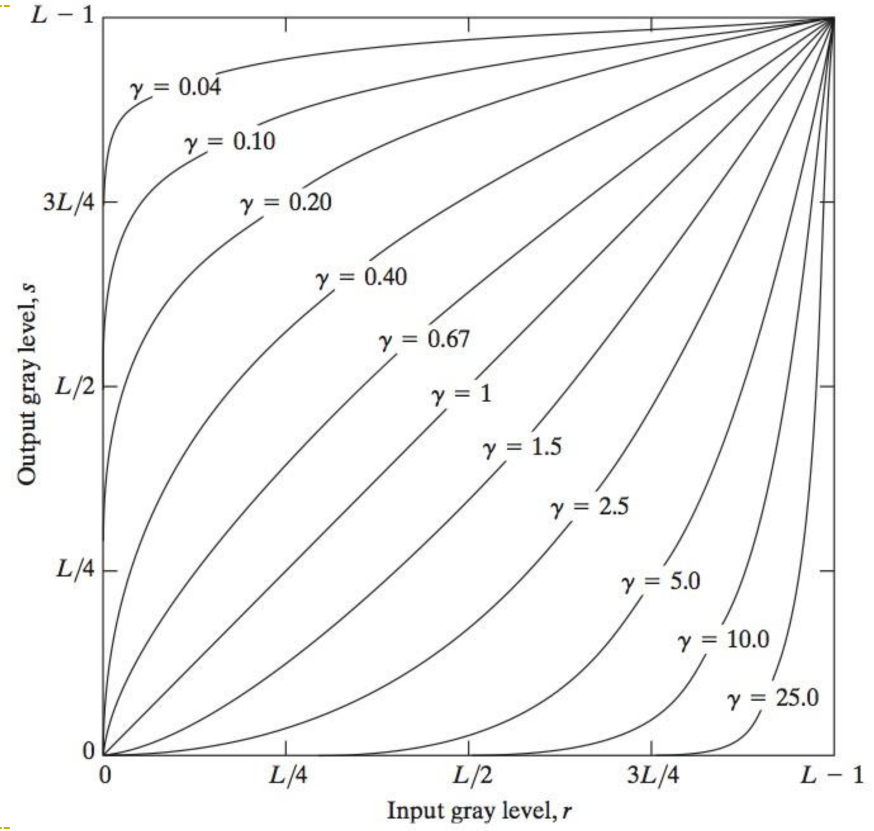


$$s = T(r) = c\ log(1 + r)$$

# Standard Intensity transformations



# Power-Law (Gamma) Transformations



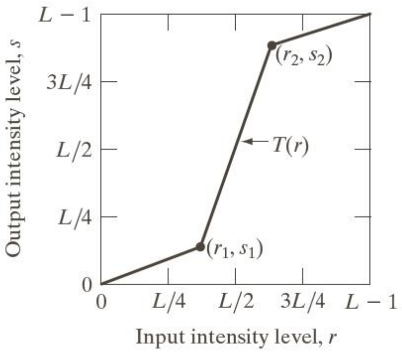

$s = c\, r^{\gamma}$

# Power-Law Transformations

a b
c d

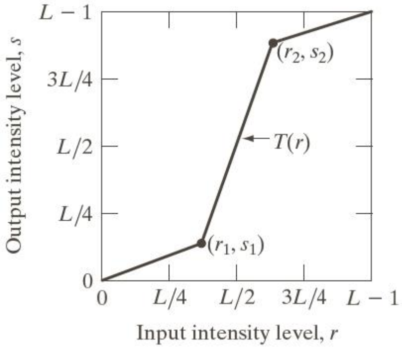
**FIGURE 3.9**
(a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0$, and 5.0, respectively. (Original image for this example courtesy of NASA.)

# Piecewise-Linear Transformations




- Can be arbitrarily complex
- Finer control over transformation

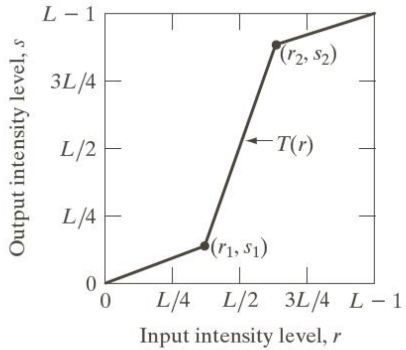
# Piecewise-Linear Transformations - Contrast stretching

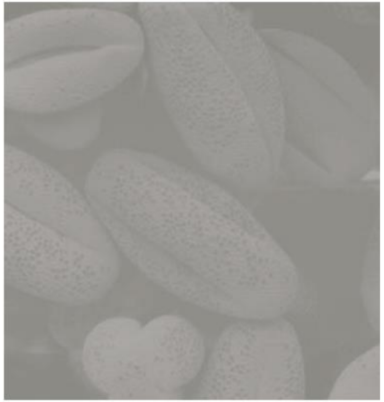


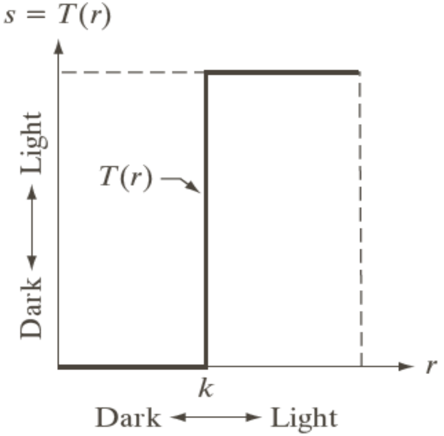

- Expand intensity range to full intensity range

What are the constraints on (r1,s1) and (r2,s2) ?

# Piecewise-Linear Transformations



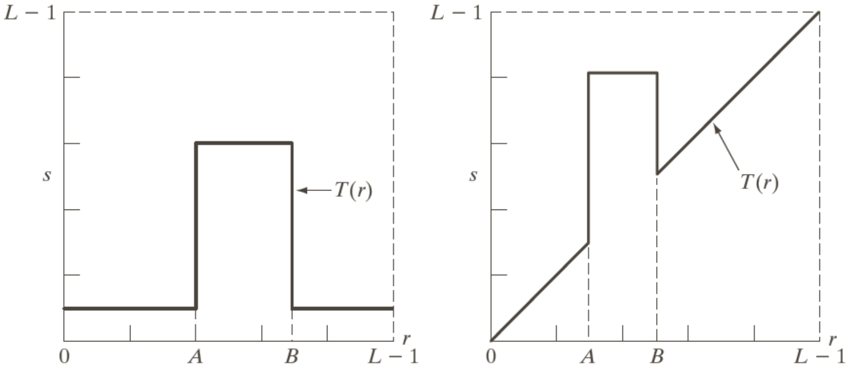


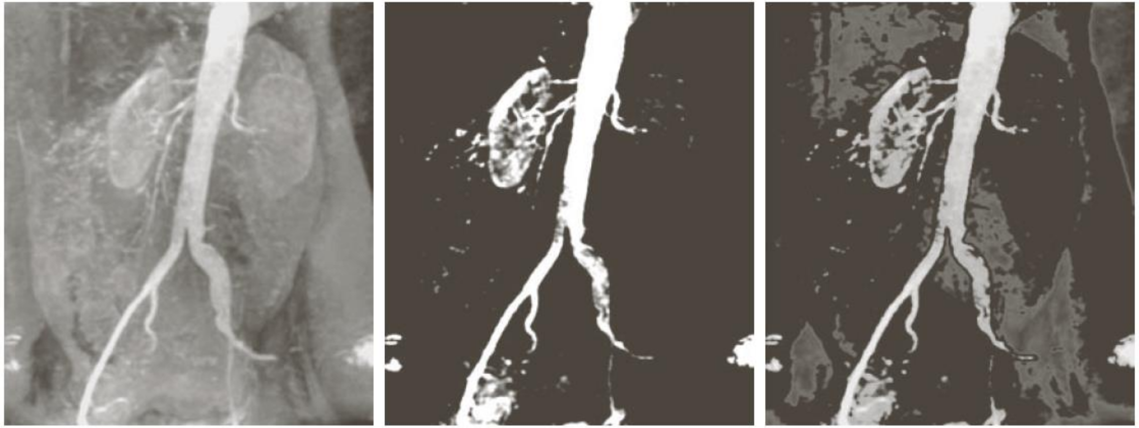

(r1,s1) = ?
(r2,s2) = ?

# Intensity Slicing

a b

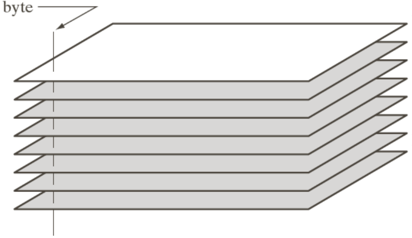
**FIGURE 3.11** (a) This transformation highlights intensity range [$A$, $B$] and reduces all other intensities to a lower level. (b) This transformation highlights range [$A$, $B$] and preserves all other intensity levels.



a b c

# Bit plane slicing




| | | |
|---|---|---|
| a | b | c |
| d | e | f |
| g | h | i |

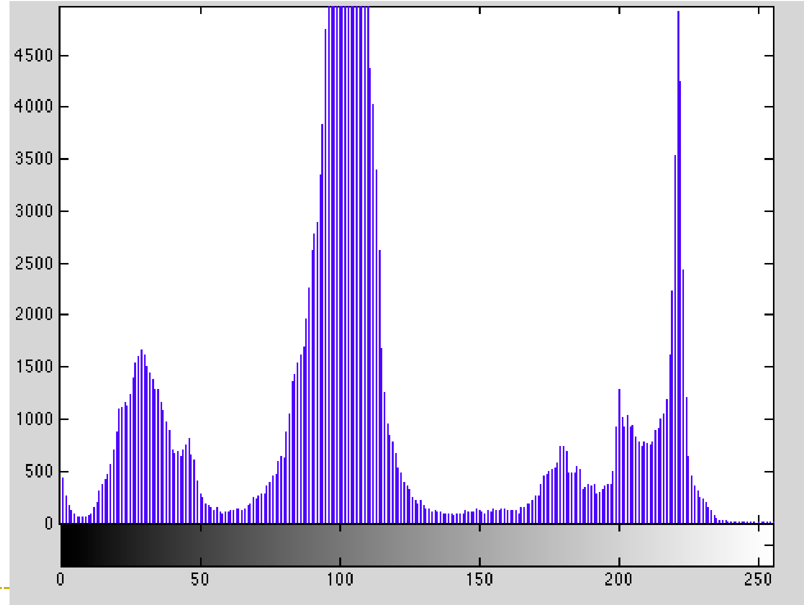
**FIGURE 3.14** (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

# Histogram

$$h_r(i) = n_i$$

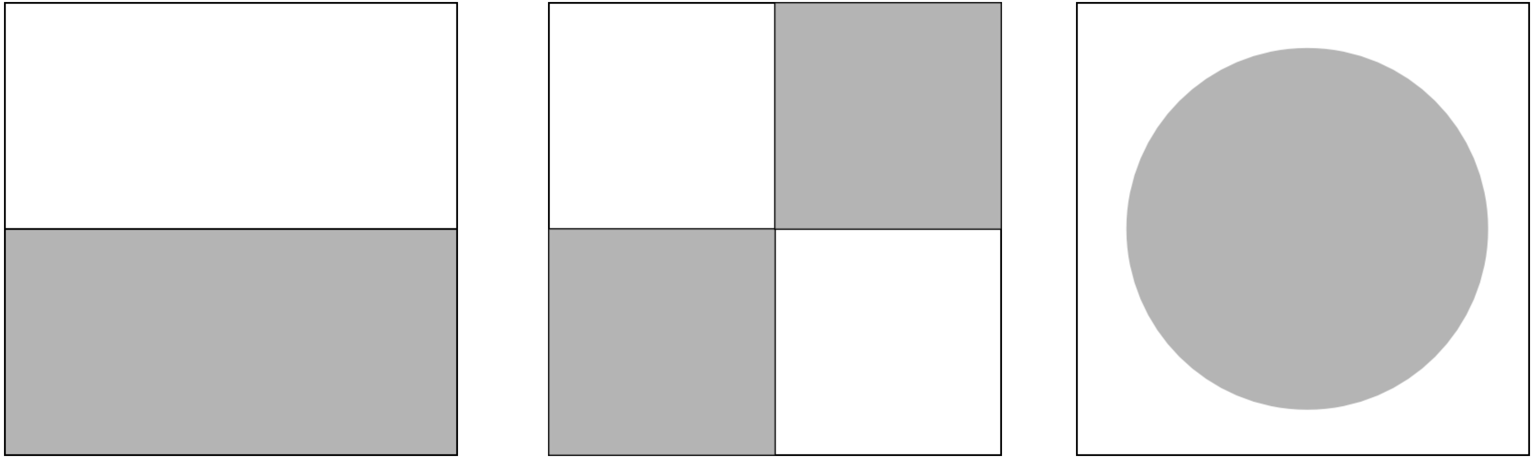
i → intensity value, range [0, L-1]

$n_i$ → number of pixels with intensity i

# Histograms

- Different images can have same histogram



- No information about spatial distribution of intensity values

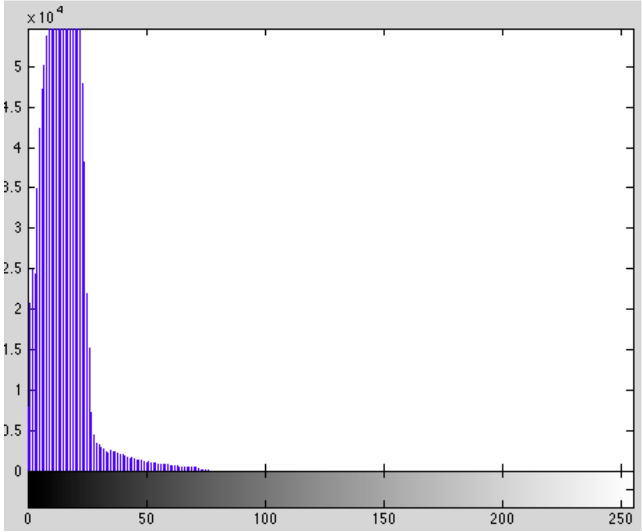
# Histograms

- What can we infer from histograms?


Histogram viewing standard in most DSLR cameras

# Histograms

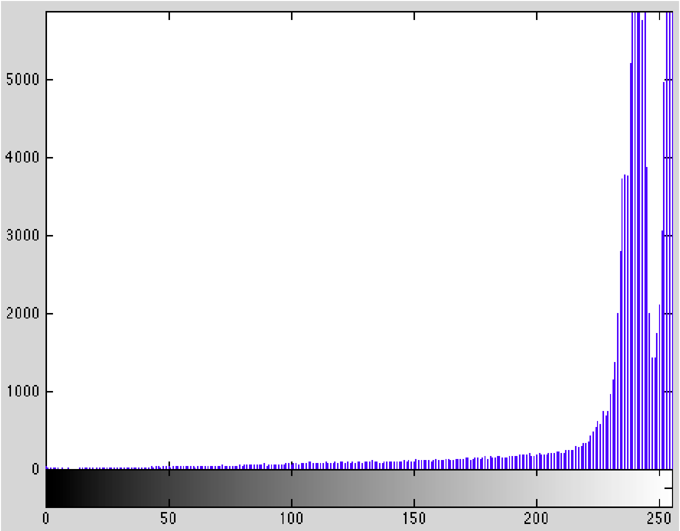
- Histograms and brightness




Under exposure

# Histograms

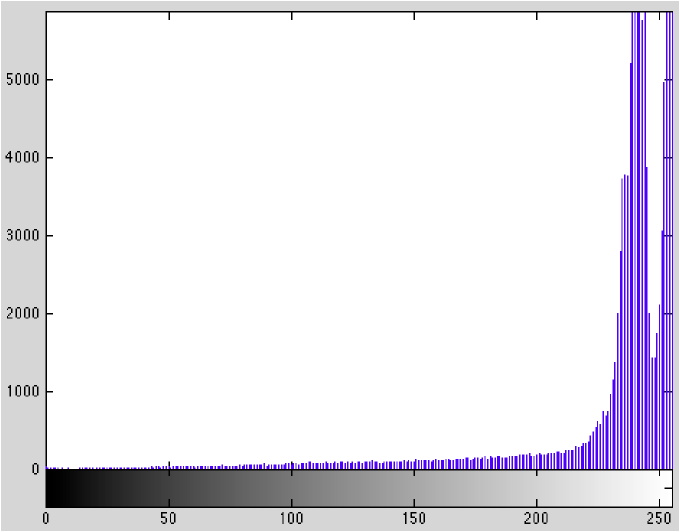
- Histograms and brightness


Over exposure

# Histograms

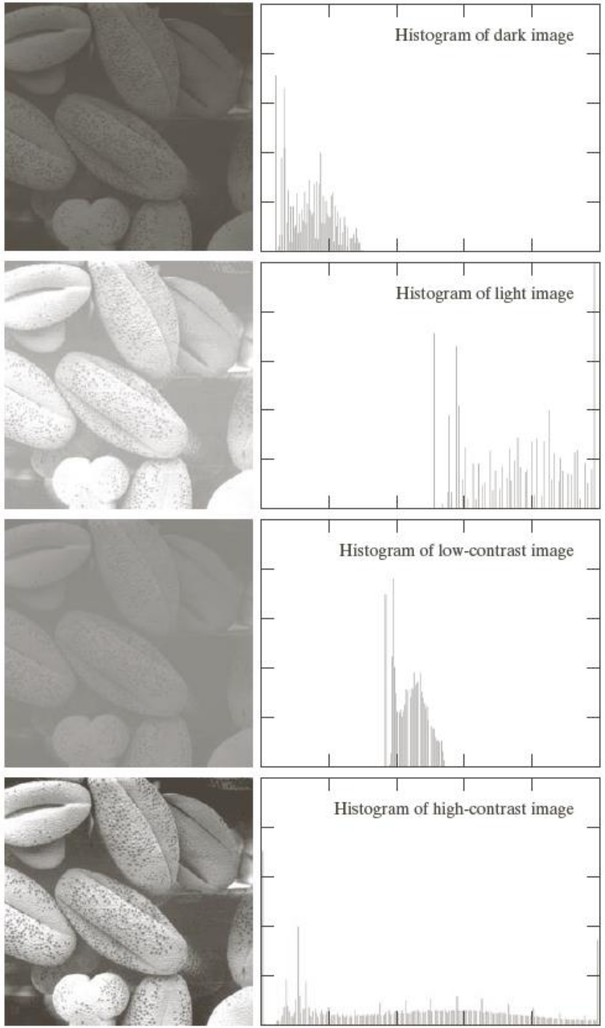
- Histograms and brightness

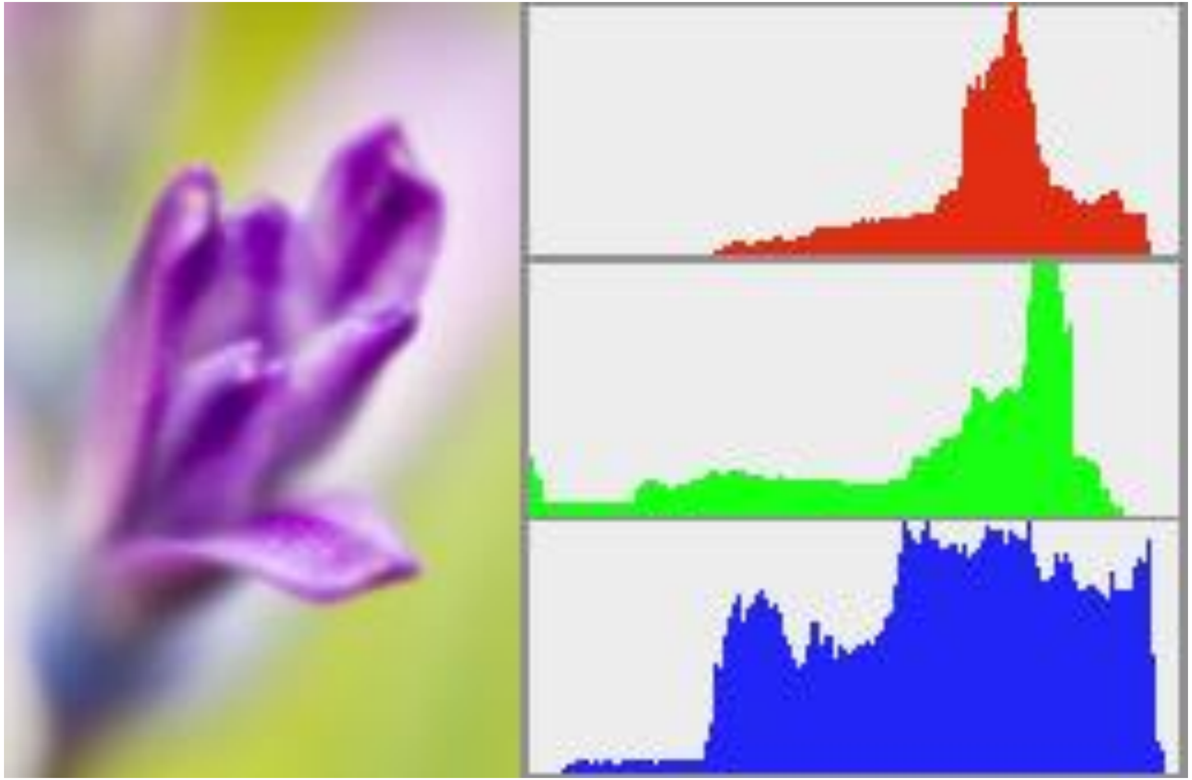

Over exposure

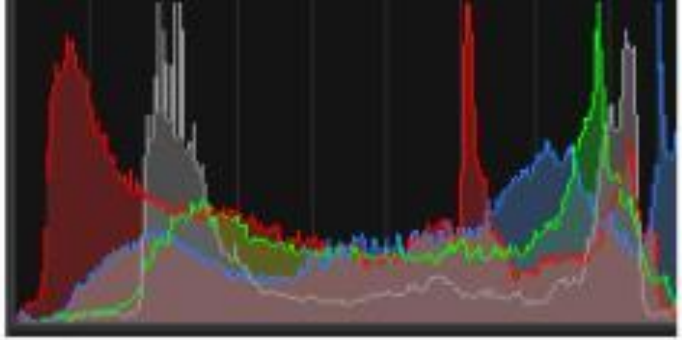
# Histograms

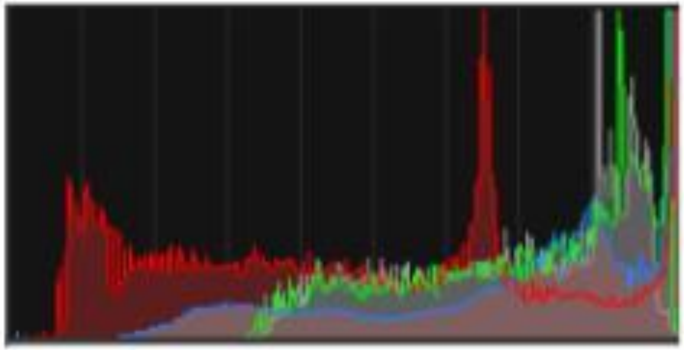
- Histogram and contrast

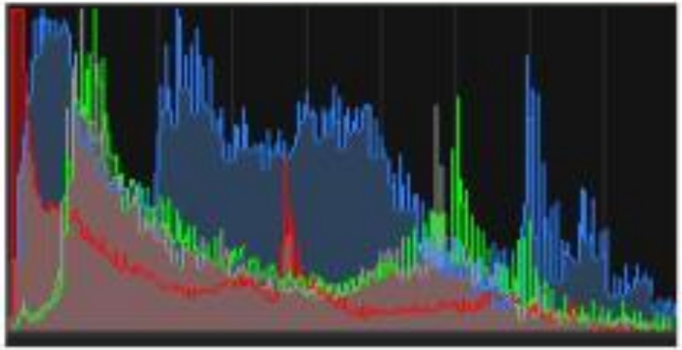


# Histograms for RGB images







# Time for Show & Tell!

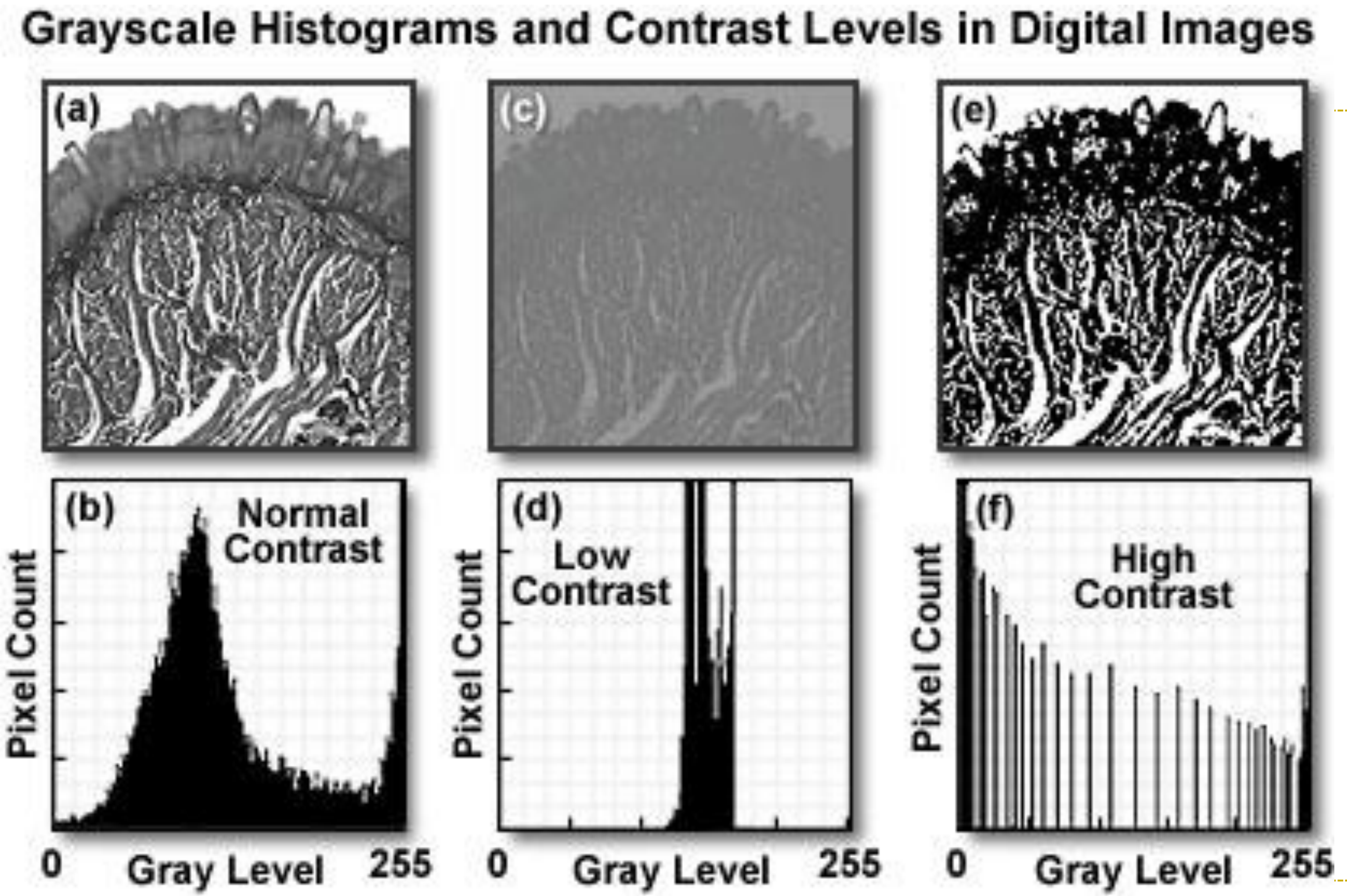
# Time for Show & Tell!


# Brightness & Contrast

*Subjective*

- Brightness vs. Luminance vs. Contrast

*Objective*


Grayscale Histograms and Contrast Levels in Digital Images
(a)
(c)
(e)
(b)
Normal Contrast
Pixel Count
0
Gray Level
255
(d)
Low Contrast
Pixel Count
0
Gray Level
255
(f)
High Contrast
Pixel Count
0
Gray Level
255

# Simultaneous Contrast & Perceived Brightness